Portable Nutrient Data Collection System

DESIGN DOCUMENT

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Client: Professor Long
Advisor: Professor Que
Ben Theisen – Team Lead
Michael Rupert – Web Master
Zakk Belloma – Key Concept Holder
Ryan Young – Key Concept Holder #2
Ben Engebrecht – Communication Leader
Logan Boas – Communication Leader #2
May1719@iastate.edu
http://may1719.sd.ece.iastate.edu

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Contents

1 Introduction

1.1 PROJECT STATEMENT

This project deals with a portable system that will be used to analyze water in the field. The purpose of this is to determine whether there are certain nutrients in the water in certain locations. This system has two methods of testing the water. The first is sending a high voltage across a small reservoir of water that essentially vaporizes the water creating a light that goes into a fiber optic cable and into a spectrometer[1]. The second method is shining a strong enough light through the water sample that then goes into a fiber optic cable connected to the spectrometer. After the data is produced by the spectrometer, it will be sent through our system and out to an app for the user to easily view the data.

1.2 PURPOSE

This project could be very beneficial in several capacities, most notably in agriculture and environmental sciences. Agriculture could use this system to ensure that the water they are using is free of any harmful chemicals. This could help farmers gain better yields from crops, use their resources more efficiently (not harming crops with bad water and having to replace them), and ultimately have better financial results from their business. Environmental studies would be able to use this system to analyze potential pollutions in hard to reach areas with other equipment. With this portable system, they would be able to keep a watch on problem areas. Also, using this system, with the analysis of the spectrometer these scientists would know exactly what is causing problems in the environment. This means that they should be able to find a solution quickly. Society would benefit greatly from both uses of this project. There would be more food coming from farms and that food would be free of the harmful chemicals that would be detected by the system. Environmentalists finding pollution in water sources and dealing with the issues would lead to a cleaner environment and creating a cleaner place for people to live.

1.3 GOALS

As a group, we hope to create a working model by the end of both semesters that will be shown to industry professionals. In doing so, this system could find its way into the hands of people who need it. Before the final product, we will need to have a prototype to perform final testing, our goal is to have this prototype done in March 2017. In addition to the base system, we aim to develop an app that can communicate with the system. Our goal is that we will have a prototype app available at the same time as the prototype system, and a fully functional app by the time we have finished the final system product.

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[1] Ocean Optics. (2016, December 5). FlameIO.pdf. Retrieved from Flame User Guide: http://oceanoptics.com/wp-content/uploads/FlameIO.pdf

2 Deliverables

To meet our goals, we will need to develop the system that will deal with the data from the spectrometer. We will also need to develop an app meeting the functional requirements.

System

-Able to communicate with the spectrometer

-Voltage booster

-Wirelessly sends data to the app

-Low power consumption

-Weather resistant

App

-User friendly interface with a tutorial

-Wirelessly receives data from the system

-Able to control the system from the app

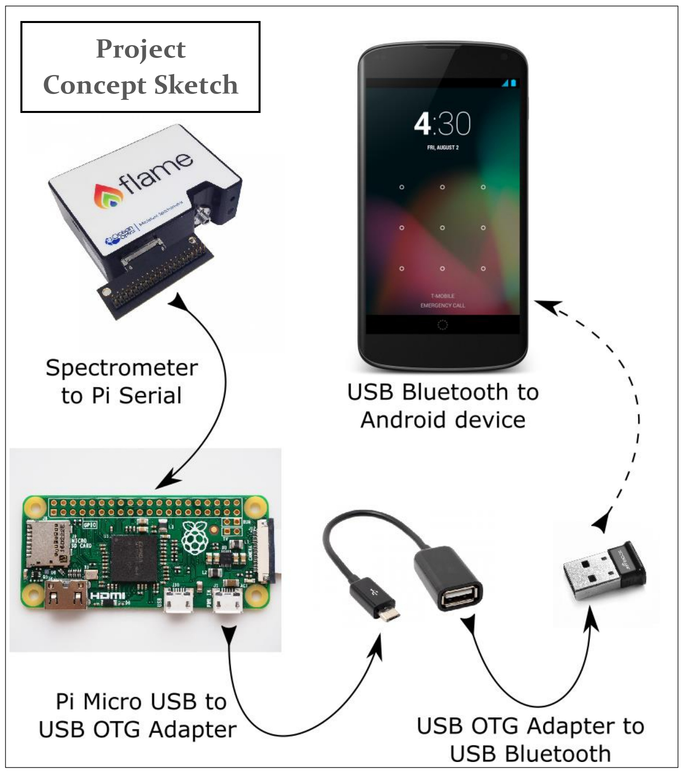
-Stores data in a local database

-Communicates with a cloud server

3 Design

The base of this project is getting data from the spectrometer to a more mobile friendly application. Currently the spectrometer needs to be connected to a computer via a USB cable and the data is only shown in an Ocean Optics application. There are two methods of extracting data from the spectrometer, the first, through a USB connection, the second, using GPIO pins. Originally, we had planned to use the USB method. Our team performed some testing with the USB connection using the Ocean Optics data sheet to send commands to the spectrometer. However, we were unable to establish the serial connection over USB so the decision to move to GPIO serial communication was made.

Two methods of testing samples have also been tested. The first being the micro discharge method that uses the voltage booster[2]. Second, using an LED light to shine through the sample and into the fiber optic cable connected to the spectrometer. The second method was eliminated rather quickly due to some physical constraints. This system is required to be portable. The LED method required a rather large light source that required too much power to sustain and would have made the system difficult to use in the field. So, the micro discharge method has been decided to be our approach to how data from the samples is acquired.



Communication from the microcontroller to the app came down to two ideas. Bluetooth communication versus communication over Wi-Fi. However, it was an easy decision to go with Bluetooth. It can work in areas without some sort of internet connection, which is very probable for where this system would be used. So far, we have begun to implement Bluetooth into the smartphone app. We can find the device but currently are running into issues creating a Bluetooth server for communication between the module we are using and the app.

Storage of the data from samples is also very important. The user will likely need to go back and analyze data collected earlier. This will be achieved with a local database that can later upload the data to the cloud. Using a system called Firebase will help us achieve this functionality. Firebase has been added to the app and is currently being tested for storing data sent to the app.

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[2] Coates, Eric. "Learn about Electronics." Boost Converters. N.p., 8 Nov. 2016. Web. 05 Dec. 2016.

3.1 SYSTEM SPECIFICATIONS

The system needs to reasonably portable. It can be assumed that a user will have a bag of some sort to carry the system in the field. Still, form factor is one of the deciding factors that we have used in selecting what components to use. Another assumption is that the user will have access to power to charge the system after a day of use. Currently the app is being developed for Android systems, so it will be assumed that the user will have some sort of android device capable of Bluetooth connection with a system version of 4.0 or more recent.

3.1.1 NON-FUNCTIONAL

-Interface should be simple and have a tutorial

Tutorial should be able to walk users through the system for them to use it correctly.

-Entire system needs to be portable

Users will need the system in a field and should be able to carry easily.

-System should last for 50 trials on one battery life

Users in the field should be able to perform multiple tests on one battery charge.

-Reasonable wireless range

The user should be able to have their phone with the app

-Data acquisition in less than 5 seconds

The entire process from start to displaying the data on the app should take less than 5 seconds. This will depend mostly upon how fast the spectrometer performs its function.

-One battery charge should last for a full day in the field

The battery should be able to last for a full day, or until the user performs 50 tests.

3.1.2 FUNCTIONAL

-Weatherproof/Weather resistant

This system is going to be used in the field around water and potential weather. The system will need to be able to deal with

-Wireless connectivity/Data transfer

The system needs to be able to wirelessly transfer data to the app that we are developing.

-Store data from each sample in a database

Storing data from each sample in a database will allow for the users to compare data from different samples taken in separate locations or the same location over a period.

-Test multiple samples

The system should be able to test multiple samples and should be able to store the data from each sample separately.

-Display data in human readable fashion

The app should display the data from the samples in a way that the user can read.

3.2 PROPOSED DESIGN/METHOD

Our team has decided to build off the idea from the team that worked on this project last year. The previous team attempted to make their own microcontroller to connect to the spectrometer. From there, the original team wanted to send the data to a smartphone app over Bluetooth that they had built into their microcontroller[3]. Learning from their mistakes lead us to believe that using established modules and microcontrollers is a better route for completing this project. As a result, while the general plans are the same, we have made a clean break from their implementation and are designing our own from scratch. We decided to use a Raspberry Pi as our microcontroller[4], and attempted to use a HC-06 Bluetooth module for communication to the app[5].

However, the Raspberry Pi only has one set of serial communication pins, and we needed two connections for both the spectrometer and the HC-06. We initially surmised that other pins on the Pi would have decent performance with a software serial solution, but under testing, the speed was not fast enough to meet our requirements. Instead, we began looking at alternatives and decided to use a generic USB Bluetooth dongle. This solution provides us with the required performance and has the added benefit of further decreasing the overall size of the project.

Our team has also decided to do the micro-discharge approach to test the water sample rather than the Spectro photometer method because the photometer method required chemicals put in the water sample, which makes the portability and convenience of the sampling system less appealing. The photometer method also required a very bulky light that consumed an extremely large amount of power to operate.

Voltage Booster – With there being no available voltage boosters that step 5 V up to 390 V from a reputable supplier or any data sheets, we decided to design our own to make sure that it meets all the needed specifications and is compatible with the connectors we will decide to use. The voltage booster needs to be relatively small, charge to proper voltage consistently and quickly, only supply a short burst of 390 V, and be as energy efficient as possible.

Serial Communication - Our Team has decided to use RS232 serial communication to communicate with an Ocean Optics Flame Spectrometer. We plan to use a Raspberry Pi to send and receive information with the spectrometer with the help of the Pi4J library[6]. The Pi4J library will provide us with methods to listen for data sent from the spectrometer and methods to send data to the spectrometer via RS232 communication ports on both devices. Once we have retrieved data we plan to use Bluetooth communication to send the data to a phone app, which will process the data as needed.

Bluetooth – This communication between the app and the microcontroller will serve two purposes. First, to transfer the data from the spectrometer to the app. Second, to be able to send

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[3] Senior Design Group May1633. (2016, December 5). Portable nutrient data collection System. Retrieved from Senior Design May1633: http://may1633.sd.ece.iastate.edu/index.html

[4] Ada, Lady. "Introducing the Raspberry Pi Zero." Adafruit Learning System. Adafruit Industries, 05 Dec. 2015. Web. 5 Dec. 2016. <https://cdn-learn.adafruit.com/downloads/pdf/introducing-the-raspberry-pi-zero.pdf+>.

[5] Olimex LTD. (2016, December 5). hc06.pdf. Retrieved from OLIMEX LTD: https://www.olimex.com/Products/Components/RF/BLUETOOTH-SERIAL-HC-06/resources/hc06.pdf

[6] Savage, Robert. "The Pi4J Project - Home." The Pi4J Project - Home. Pi4J Project, 26 Aug. 2016. Web. 05 Dec. 2016.

commands from the app to the microcontroller to control the spectrometer. This will allow the user to initiate tests from the app, eliminating the need for physical access to the spectrometer.

Smartphone app – An app will allow users to view data right away in the field. This can be useful in many ways. It could increase efficiency of the device by allowing users to know if they are testing in the right place. The app will have the ability to control the spectrometer in the system through Bluetooth and serial communication, store data from samples in a local database, and also upload that data to the cloud when desired. Uploading data to the cloud will allow users to analyze the data further and with more powerful systems than a simple smartphone app, leading to a better result from the system.

3.3 DESIGN ANALYSIS

Voltage Booster – So far, we have designed a circuit that will meet our needed specifications, this design has changed multiple times. The capacitor needed to create a stable constant voltage was much larger than was needed for the portability of the entire device. Then we learned that we only needed a short burst of 390 V to get a result from the spectrometer. After redesigning the circuit, we have ordered and received the components. Moving forward we will assemble and test the circuit. Upon testing the output, we will make any needed adjustments to generate the needed output. We should experiment with the capabilities.

Serial Communication - So far, our team has attempted serial communication with the spectrometer via USB. Our attempts with USB were unsuccessful, as we could not detect the spectrometer device over USB connection. Moving forward we planned to use RS232 communication instead. Initial tests with RS232 communication has given us trouble with the spectrometer's power supply which was turning the spectrometer off when we had the RS232 communication ports connected to our laptops. After further investigation, we found that the breakout board has mislabeled pins, which were causing the power problem. We next worked on sending commands between the two devices and ran into problems with the data format for sending and receiving data. After some testing and the help of a multimeter we found that we were working with more mislabeled pins which we had to decode to make a valid connection. Moving forward, we plan to do more tests with the spectrometer connected with our Raspberry Pi and eventually have communication between all connected devices.

Bluetooth – So far, we have an app that can enable Bluetooth capability, and can scan for Bluetooth devices around you and attempt to connect to them. The app can successfully pair with the Bluetooth device. It can also send and receive data. After working with Bluetooth for a little while it is more complicated that initially thought, however it is the best option for communicating with the spectrometer. The final version of the app will most likely look different and consolidate starting Bluetooth and the scanning process into a single step and have communication capability.

Firebase – This is the tool we are using to implement the database part of the project. It can store data locally and have functionality to upload that data to the cloud when possible. This is perfect for our needs in this project. Currently Firebase has been added to the app and we are developing a page of the app to display the local database information. Additionally, in the future, Firebase supports different users. So, we can add some security measures into the app. Separate users should have separate login information and Firebase can be used to support that. Each user having their own account ensures that each user gets credit for their work and data from different users can be analyzed separately. This will also eliminate the potential for a non-authorized user to use the system and generate garbage or harmful data.

4 Testing/Development

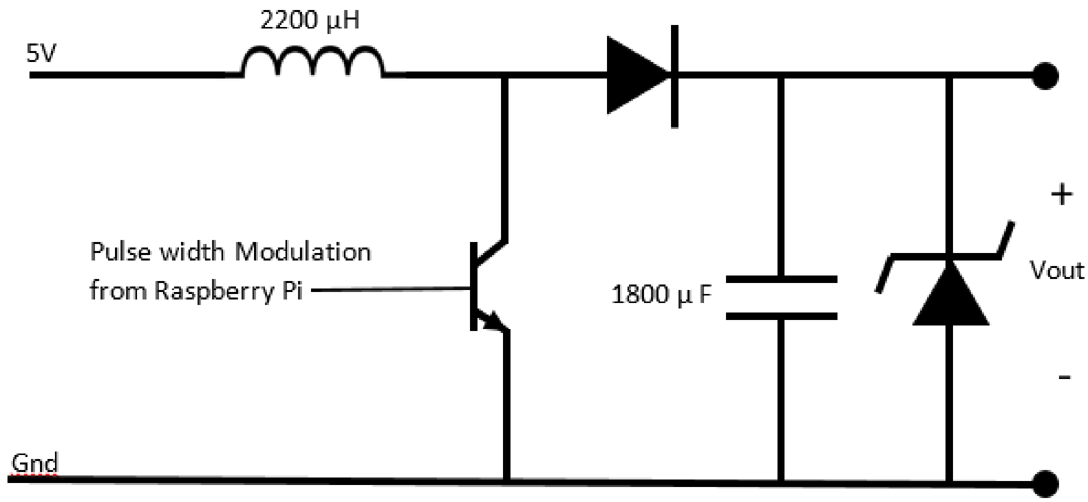
4.1 INTERFACE SPECIFICATIONS

Serial Communication – We are using a Raspberry Pi connected to an Ocean Optics Flame Spectrometer via RS232 ports. We are also using the Pi4J library to help us preform serial communication between the two devices.

The user will interact with a smartphone application to utilize the system. This interface is required to be simple and straightforward for convenient use in the field. A tutorial explaining how to use the app and all the functions of the will also be included. The app will interface with the spectrometer through Bluetooth to set parameters and modes of the spectrometer, as well as initiate testing and gathering data. Another part of the app interface will be a local database. This will allow the user to look through the data that they have collected and make decisions based on that data.

4.2 HARDWARE/SOFTWARE

Voltage Booster – Used to step up the voltage from the 5 V battery to 390 V for the micro-discharge device. The circuit we designed is shown below. The Zener diode is rated for 390 V Zener voltage, and the rest of the circuit parts are rated for over 450 V. The transistor will be turned on and off by pulse width modulation (PWM) generated by the raspberry pi, through one of the pi's GPIO pins. The accuracy of this device is important so we have the same output voltage for every test sample, for the most accurate results. The accuracy is also affected by the tolerances of the individual components. That is why when selecting the parts we selected the smallest tolerances that were available to have the most consistent output voltage. The voltage booster operates by having a square wave, PWM from the raspberry pi, switching on and off the transistor. When the square wave is at its peak it turns the transistor on and the current passes from the inductor to the transistor. This builds the magnetic field within the inductor. When the square wave drops down the transistor is turned off. With the transistor off the current is then passed through the diode and charge the capacitor because it can not pass through the rear facing Zener diode. The inductor also produces a back e.m.f. after the transistor is turned off, due to the change in the current. This back e.m.f. can be calculated by E = -L*(change in current)/(change in time taken for current to change). This additional voltage is also stored within the capacitor. Then the square wave changes again the diode prevents the capacitor from discharging through the transistor and the inductor builds up its magnetic field. The capacitor does dissipate a small amount but the capacitor charges much faster. This switching process continues until the output voltage reaches the Zener voltage of the Zener diode, 390 V. Once the Zener voltage is less than the output voltage passes through the Zener diode to the Micro-Discharge to test the water sample.



Micro-Discharge – The team in phase one designed this device to test the sample of water by arcing the boosted voltage through the water sample between an anode and cathode. The light that is produced due to this arc is detected by an optical fiber and the fiber carries the collected data to the spectrometer to be analyzed. The light of the arc is important because the light emitted by the electricity passing through each specific element occurs at a specific frequency.

Serial Communication – We are using our Raspberry Pi connected to an Ocean Optics Spectrometer along with the Pi4J library to test serial communication. These devices and library are necessary for us to perform the serial communication and collect data from our spectrometer. We also plan to use the OceanView Software, which is an Ocean Optics Software that allows us to view data from the spectrometer to verify our collected data is correct.

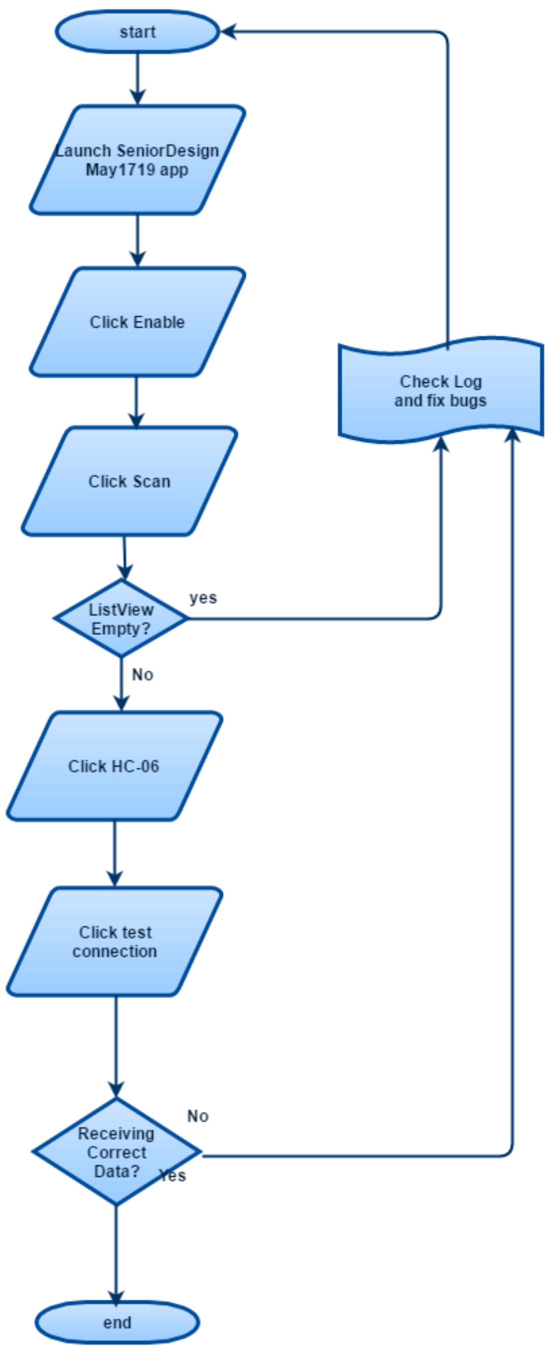
Bluetooth communication – To send data from the system to the android app, we will be using Bluetooth. This allows us to have a wireless connection between the system and app which provides flexibility to the user. This communication will be achieved with a HK 06 Bluetooth module.

Firebase – This is our solution to the database demand of this project. The system will be used predominantly in the field. This means that there may not be any sort of connection to the internet during testing. Even though there may not be a connection to the internet, the app will still store sample data in a local database. Once an internet connection is established, the sample data from the local database can be uploaded to the cloud using the Firebase API.

Power – Our solution for powering this device needs to be relatively portable, considering that one of the functional design specifications for this project is that it needs to provide portable analysis. Thus, a 13,000mAh battery with two USB discharge ports was chosen. This provides us with two 5V power supplies with a total of 3A. We measured the Raspberry Pi and spectrometer and discovered that they both draw around 350mA. This mean that this low-cost battery pack can power the device for a total of 37.14 continuous hours, which is more than enough for this design.

4.3 PROCESS

Current Bluetooth Testing Procedure

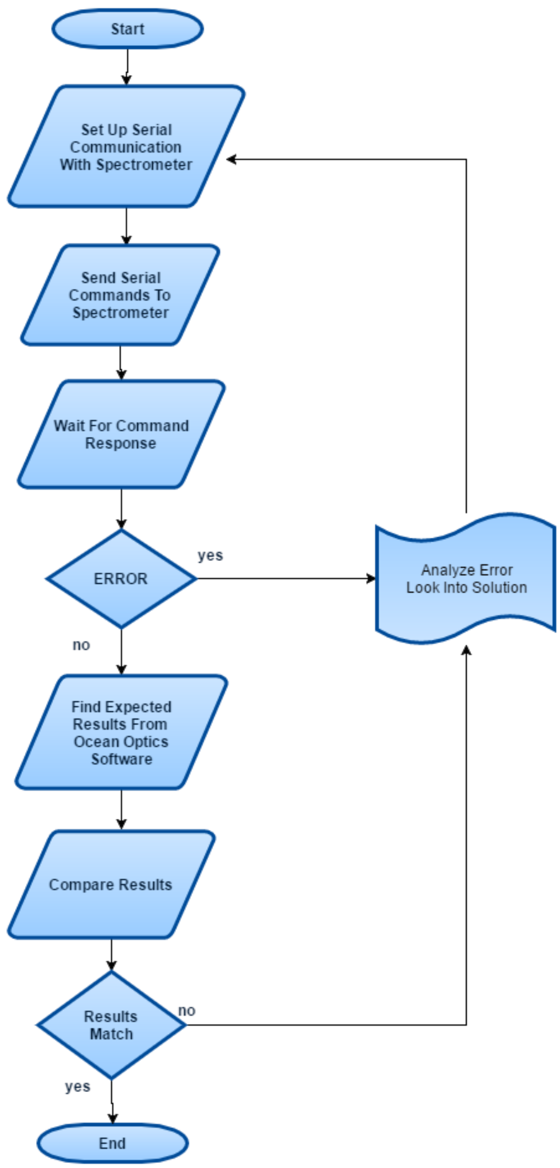


The above flowchart is the current test method for the app. It basically just involves going through the app and ensuring everything if functioning as it should be, and if it is not to go and find the cause of the problem. It will be extended as the app gains functionality.

The testing of the voltage booster will be done with extreme caution since we are dealing with 390 V. The testing that will be done on the booster is a voltmeter on the output voltage to find the time needed to charge the circuit before it outputs, the accuracy of the output, and we will test the capability to initiate the booster through the raspberry pi, for the app on the phone to start the water sample testing.

The micro-discharge device has been tested by having a powerful light shine through the water sample with specific chemicals in the sample and analyzing the results using the spectrometer. It is in the process of being tested by using a voltage source set to 390 V burst and analyzing the spectrometer's output. This test is the most like using the voltage booster.

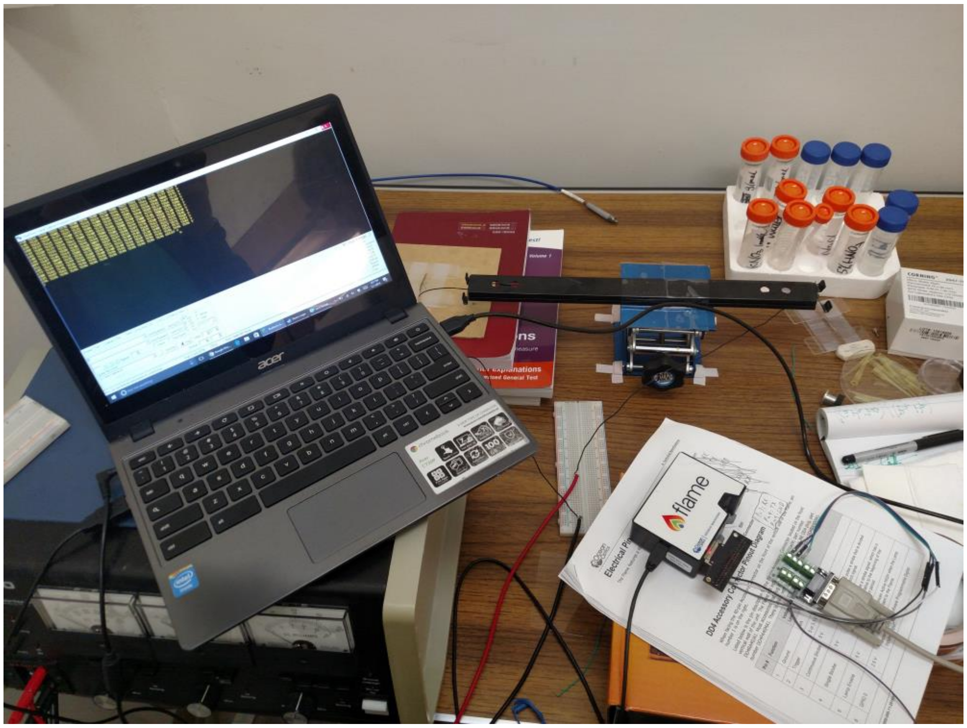
Current Serial Communication Testing Procedure



The above flowchart is the testing methods used for serial communication. We start by setting up our serial connection with the spectrometer and attempt to collect data from the spectrometer by sending a command over the serial connection. If we receive an error, then we consider what caused the error and try to fix it and repeat from the start. If we do not receive an error then we get expected data from ocean optics software provided with the spectrometer and check that our results match. If the results do not match we look into what is causing the problem, try to fix it, and repeat from the start. This process is preformed multiple times to ensure that the device works.

5 Results

For sending and receiving commands through serial communication to the spectrometer we have had some success and failures. We have learned that USB communication was not the correct approach. We have also managed to set up a connection with the spectrometer via RS232 connection. More recently we managed to send commands to the spectrometer and receive spectral data. Moving forward we will establish a connection with our raspberry pi and use the pi4j library to handle future serial communication.



Current testing setup

Currently, the app is able to connect to the Bluetooth module. The app can search and find the module as a potential device to connect to. The app can send data to the device and also receive data sent from the device. Once this connection is established we have code written that will allow us to test sending commands to the microcontroller through the Bluetooth connection.

We have successfully integrated Firebase into the app. This means we can begin setting up our local database. In addition, we can begin to connect our app to a cloud database. Once we can upload data to the cloud, we have an additional goal for the project of developing web based view of the data for more thorough analysis of the data.

Looking through a research paper, we have located the range of wavelengths and intensity that nitrate will output from the micro discharge method of data collection. This was done with help from a graduate student who is working with Dr. Long on this project. This means that we can focus our data collection from the spectrometer. So, we have created a set of parameters that will be sent to the spectrometer to collect the data that we specifically need. Instead of looking at the full range of data that is output from the spectrometer, we can focus on wavelengths of approximately 300 – 500 nm. With this smaller range, the data acquisition and transfer to the app should take even less time. Another benefit of this is that with less data transfer and lower up time of the system, we can reduce the specifications and requirements on our power supply.

6 Conclusions

So far, we have created a design of the system. Through vetting out our options of how to extract data and send it to the smartphone app, we have decided on using serial communication from the spectrometer to a raspberry pi zero. From there, the raspberry pi will send the data to a Bluetooth module that can be connected to in the smartphone app. This process can be reversed as well, so the app will be able to send data to the spectrometer. We decided this is our best option for several reasons. First, it will limit need for physical access to the spectrometer. Second, it will allow the user to control the system from a simple interface in the app. Third, this method will not require excessive amounts of power, meaning the system should be able to perform its functions for a full day on a full charge.

Deciding on the micro discharge method of data acquisition was a straight forward task. When compared to the other method of shining an LED light through the chemically treated sample, micro discharge was the clear winner. The LED method required much more power, space, and preparation. We want this system to be portable for users to carry in the field and require less power. The LED was behind the micro discharge method on both of those fronts. So we are creating a voltage booster that will fit the requirements to perform the micro discharge method of data acquisition.

We have goals of creating an enclosed weatherproof system containing the parts from above. This will create another safety net from any complications in the field, and safety for the user from the micro discharge method of data acquisition. Another goal is once the physical system is created, to link the data to a cloud based system that the users can view on a computer to perform more analysis than the smartphone app can. Creating this system will greatly simplify nutrient analysis and could lead to many benefits for the user. With a simple tutorial, the user will be able to analyze any water sample and diagnose any potential issues.

7 References

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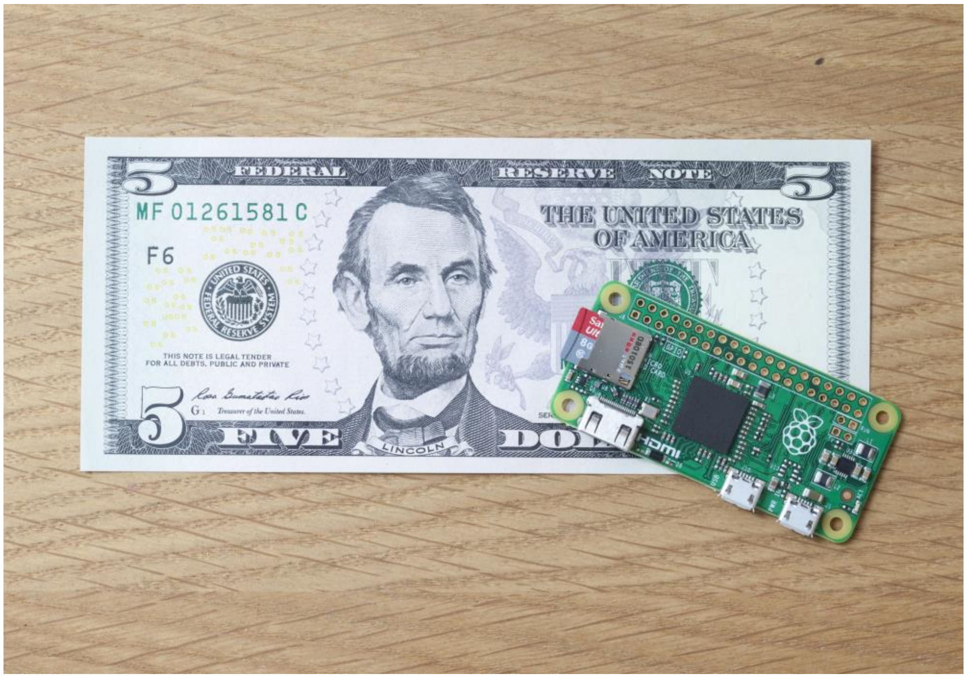
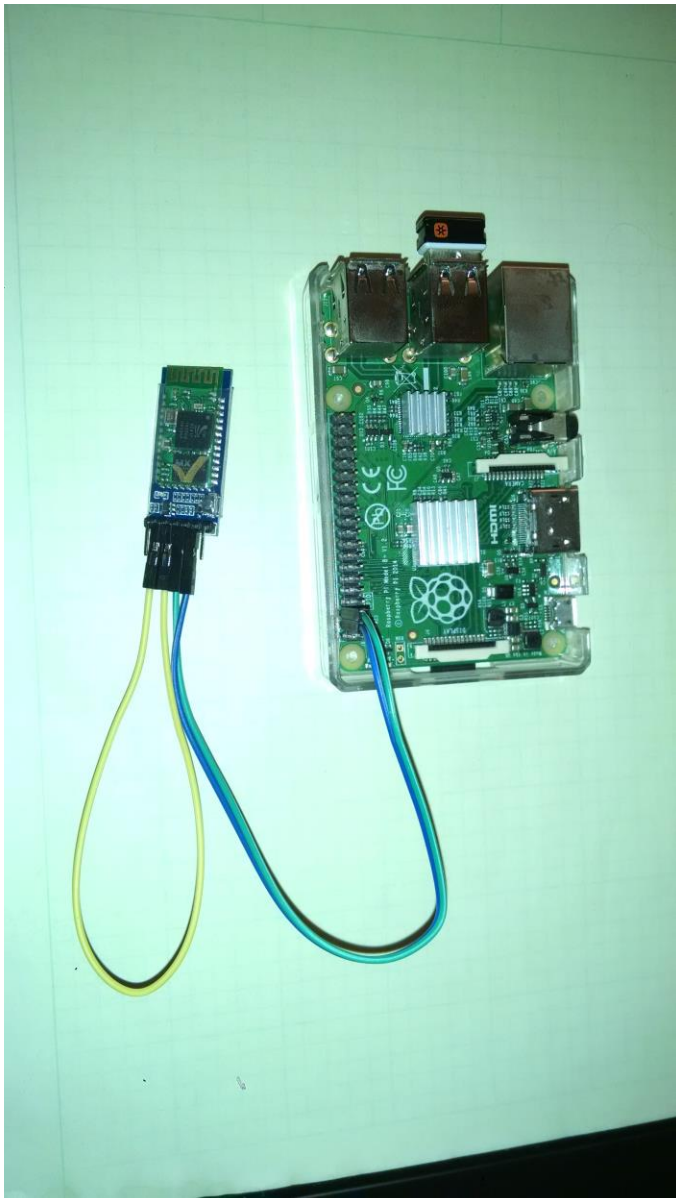
8 Appendices

Pi Zero- 5 dollar bill for scale. (also costs 5 dollars).



Bluetooth testing setup:



Flame Spectrometer and Breakout Board